Ocean Indicator Updates: Spring 2007

The year 2006 marked what now appears to be the beginning of a transition from the poor ocean conditions observed in 2004–2005 to very good conditions in 2007. The problem with ocean conditions in 2006 was twofold. First, although upwelling did begin in early May, atmospheric conditions changed drastically after just 2 weeks of upwelling. Several strong southwesterly storms moved up the coast and may have erased or "reset" any signature of upwelling. Thus, although the physical spring transition was somewhat early (3 May), the biological transition did not occur until 30 May.

Second, because some indicators are based on summer averages (May–September), they did not capture the poor ocean conditions that prevailed from April through mid–June. Some improvements were seen in summer 2006, but these did not begin until June or July—2 months after juvenile salmon entered the ocean. Thus, salmon encountered poor ocean conditions during their first weeks in the ocean, which likely had a negative impact on survival.

Becuase of this problem, we are now working to subdivide indicators into two components. The first will characterize ocean conditions in late winter/early spring (March–May), when juvenile salmon are arriving at sea. The second component will consist of indicators averaged from June or July through September, when salmon that survive ocean entry experience rapid growth. Below is a synopsis of indicators that changed during 2006-2007. Time series for the changes are shown in figures linked to each synopsis.

Pacific Decadal Oscillation—A warm–phase PDO prevailed during most months from August 2002 through July 2006. Since July 2006, PDO values have either been negative or near zero. A PDO of zero indicates a neutral state, which suggests "average" ocean conditions (Figure 5).

Sea Surface Temperature—A "warm ocean" trend in SSTs began in November 2002, but abated from late 2005 through early 2006. From June 2006 to May 2007, cooler–than–normal SSTs have been observed in the coastal upwelling zone. Therefore, implications for salmon survival are "mixed" in terms of SST: warm SSTs in early 2006, when salmon first went to sea, were a negative indicator, but cooler SSTs, which have continued into 2007, are a positive sign (Figure 5).

Deep Water Temperature and Salinity—Temperature and salinity of deep upwelled water indicated upwelling of intermediate strength in 2006. Measurements from the 50–m depth were again taken from one of our baseline stations 5 miles off Newport, OR. Temperatures at 50 m were average compared to those of our 11–year time series of this data. Salinity values were intermediate, being similar to the summers of 2003-2005. This indicated upwelling of average strength during summer, which means upwelling was weaker in 2006 than in the cold (and productive) summers of 1999-2002 (Figure 12a).

Copepod Biodiversity—Copepod biodiversity, or species richness, remained relatively high during summer 2006, a result of warm ocean conditions. This was a negative indicator in terms of planktivorous fishes and juvenile Chinook and coho salmon. However, beginning in October 2006, species richness began to decline, and negative anomolies were seen from December 2006 through May 2007 (Figure 15).

Biological Spring Transition—the biological spring transition is defined as the date when the zooplankton community changes from a winter community of small, subtropical species (lipid-poor) to a summer community of larger, boreal species (lipid-rich).

Table 2 lists the dates when the summer and winter communities first appeared in our zooplankton samples. The difference between these two dates is defined as the length of the upwelling season. In 2006, the transition was on 30 May, a late transition date and negative indicator.

Figure 20a shows regression of coho survival as a function of the date of biological spring transition, and the length of the upwelling season. Both are based on dates of the seasonal change in copepod community structure (in spring and autumn), and both are good predictors of coho survival.

New and Developing Indicators

Zooplankton Species Composition—Zooplankton samples collected in winter 2006 and early spring 2007 show a copepod community that is dominated by cold–water subarctic species, namely Pseudocalanus mimus and Calanus marshallae. We are currently evaluating these samples for analysis of zooplankton species composition as an additional indicator of marine conditions for salmon survival.

Although the data have yet to be quantified, observations to date indicate positive conditions for salmon through May 2007. Species present indicate either a greater–than–average influx of subarctic waters (from the Gulf of Alaska) or a “normal” influx of subarctic waters containing a greater–than–average abundance of these copepods. Either case is good for fishes that feed on Neocalanus—in particular juvenile rockfish and sablefish. Thus, 2007 should be an excellent recruitment year for sablefish (black cod). Moreover, copepod biodiversity declined during winter 2007, indicating that a cold–water community has moved into the area.

Copepod Community Structure—Copepod community structure is a new index, based on the presence/absence of specific copepod community types observed during juvenile salmon trawl surveys in June and September. In summer 2006, the community of copepods resembled those seen during the warm summers of 2003 and 2004. This is a negative sign (Figure 18a).

Forage Fish and Pacific Hake Abundance—Forage fish numbers (anchovy, herring and smelts) have also been in severe decline since spring 2005 (Figure 23b). Numbers remained low in 2006, probably as a result of poor recruitment in 2005. These low numbers comprise a negative indicator, since juvenile forage fish (ages 0 and 1) are among the favored prey of both coho and Chinook salmon. Thus salmon may have been food-limited in 2006. Low numbers of forage fish in 2006 may also be a negative indicator for 2007; however we will not know the recruitment level of age-1 fish until summer 2007 (Figure 23a).

Hake, which is a potential predator on juvenile salmon, has also been found in very low numbers during the past two years. We do not know the cause of these low numbers or the impact on juvenile salmonid populations.

Hypoxia—Hypoxia continues to be a potential problem for benthic invertebrates living in continental shelf waters. Although we have no reason to believe that hypoxia is a problem for juvenile salmon, we include information on this phenomenon in the coastal upwelling section due to a general interest in this topic (Figure 7a).

Basin-Scale Winds—Wind stress over the northeast Pacific is measured from the Quickscat satellite. Monthly average winds showed conditions favorable to upwelling as early as January 2007. This is a positive indicator and the chief cause for improved ocean conditions observed in winter and spring 2007 (Figure 30).